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(54) Abstract Title

# Method of transmission with channel encoding with efficient and modular interleaving for turbo codes

(57) An encoding circuit 4 converts a flow of data elements X into several flows Y1, Y2, Y3, $Y_i$ for transmission to receiver 3. The circuit 4 consists of two encoders RSC1, RSC2 and an interleaver 15 preceding the second encoder. The interleaver 15 interleaves a binary string of n bits according to the formula:

$$h_k = a.h_{k-1} + b \text{ modulo } m$$

where k is the rank or position of a bit in the binary string, $h_k$ is the rank assigned to the bit in the interleaved string and a, b and m are integers. M is preferably chosen to be equal to n+1. The interleaver is implemented in software. The encoders may be recursive convolutive encoders.

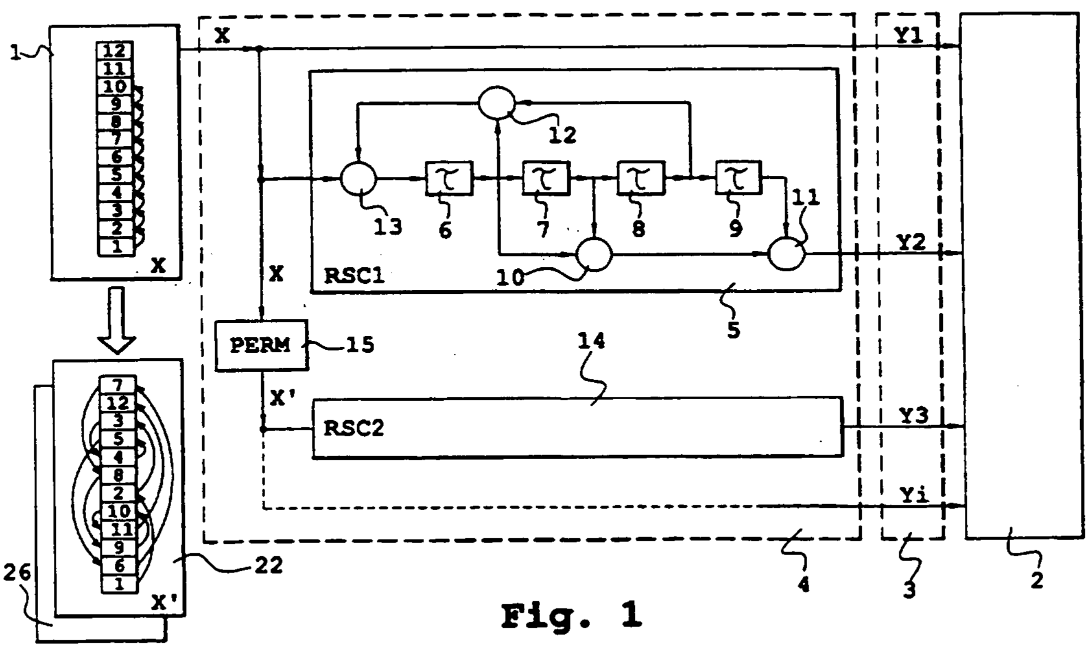


Fig. 1

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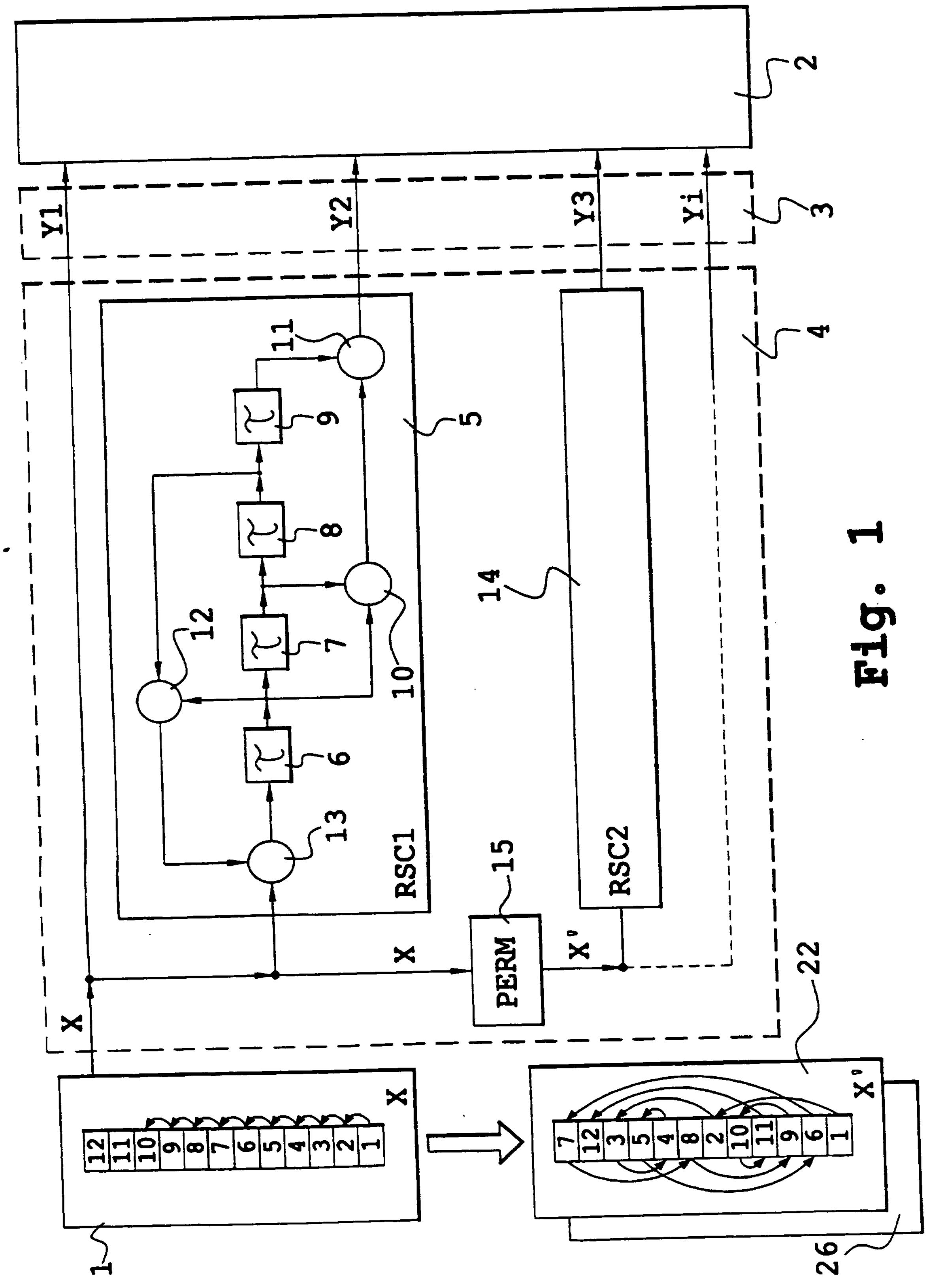
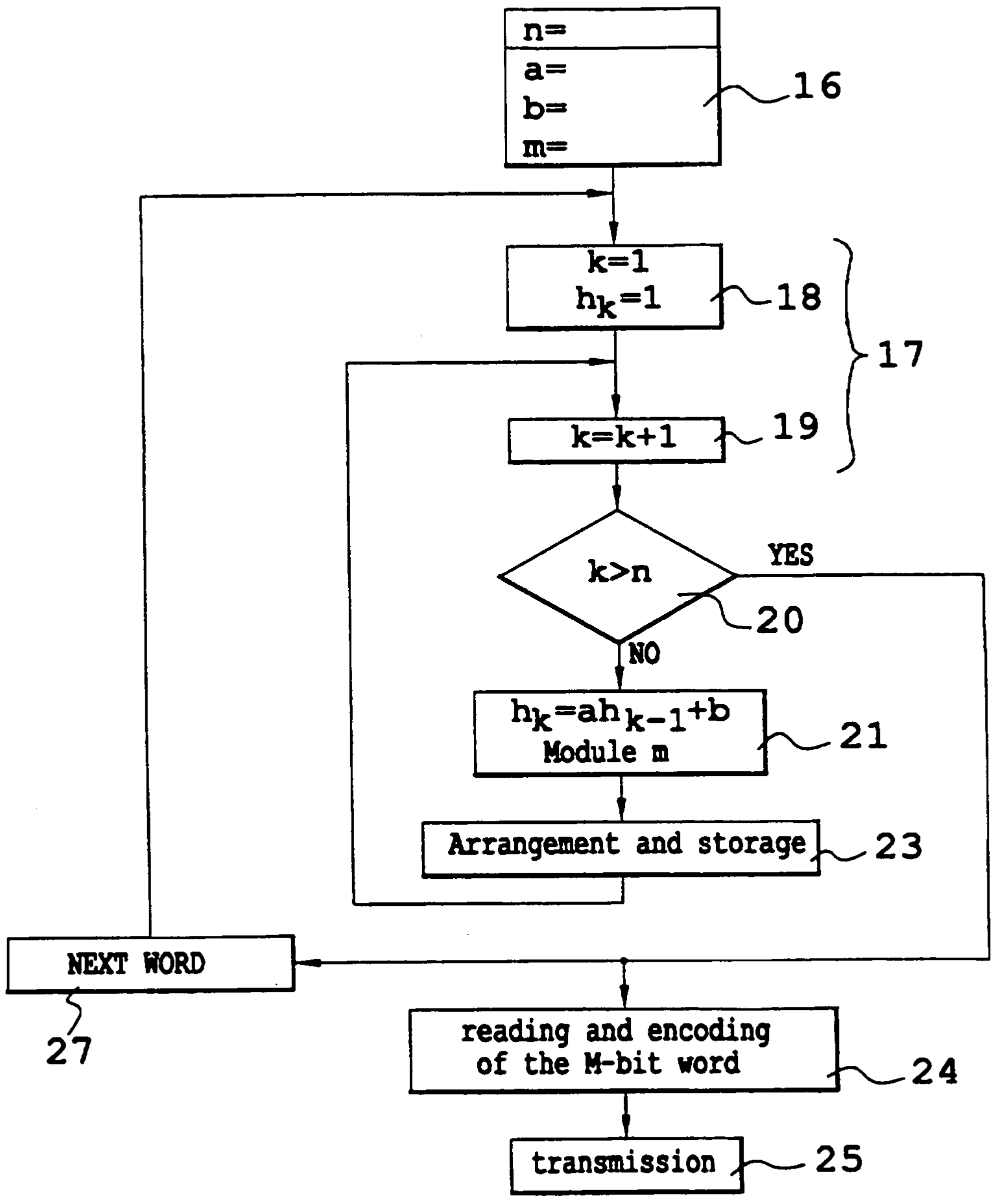


X
Y1
Y2
Y3
Yi
RSC1
RSC2
PERM
X'
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
22
26
12 11 10 9 8 7 6 5 4 3 2 1
7 12 3 5 4 8 2 10 11 9 6 1


Fig. 1



n=
a=
b=
m=
16
k=1
$h_k$=1
18
17
k=k+1
19
k>n
YES
20
NO
$h_k = ah_{k-1} + b$
Module m
21
Arrangement and storage
23
NEXT WORD
27
reading and encoding
of the M-bit word
24
transmission
25


**Fig. 2**

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# METHOD OF TRANSMISSION WITH CHANNEL ENCODING WITH EFFICIENT AND MODULAR INTERLEAVING FOR TURBO CODES

An object of the present invention is a method of transmission with channel encoding, namely with a preparation of bits to be transmitted that takes account of the transmission performance characteristics of the channel in such a way that the transmission quality is as perfect as possible despite inevitable physical defects in this channel. The aim of the invention is to propose a method in which a practical implementation of a theoretical and tested solution is simple to achieve with signal processing devices having limited power. These devices in particular are mobile telephones. The main field of application of the invention therefore is that of mobile telephony. However, the invention could also be used in satellite links. In general, the invention can be used whenever it is desired to implement a turbo code for which it is sought to obtain an efficient and modular interleaving.

In the digital transmission of information (speech, images, data, etc.), a distinction is made between source encoding and channel encoding. The object of source encoding is to compress the digital information elements to be transmitted so that they occupy the smallest possible volume, in such a way that the useful bit rate is the maximum. By opposition, channel encoding consists of the addition of the redundancy to the information to be transmitted so that the information received is more robust in the face of the errors contributed by the channel. This kind of action converts an unnecessary redundancy, namely that of the initial

information, into a useful redundancy, namely one that makes it possible to withstand transmission noises. Channel encoding therefore is of vital importance. A wide range of channel encoding methods has been available since the 1960s. The known encodings thus include convolutive encodings, BCH encodings, Reed-Solomon encodings, etc. The channel encodings used differ according to the applications in view.

The French patent application 91 05280 entitled "Procédé de codage correcteur d'erreurs à au moins deux codages convolutifs systématiques en parallèle, procédé de décodage itératif, module de décodage et décodeur correspondant" (Method For Error-Corrective Encoding With At Least Two Parallel Systematic Convolutive Encodings, Iterative Decoding Method, Decoding Module And Corresponding Decoder), as well as the document by C. Berrou, A. Glavieux and P. Thitimajshima, "Near Shannon Limit Error-Correcting Coding And Decoding: Turbo Codes", Proc. 1993 International Conference on Communications, have proposed a new encoding scheme known a turbo code whose performance characteristics approach the theoretical limit of the capacity of a channel as described in C. Shannon's theorem.

In one example where the encoding rate is equal to 1/3, with an encoding of this kind, a flow X of data elements to be encoded is transmitted in the form of three flows Y1, Y2 and Y3 of encoded data. In one example, the flow Y1 is the same as the flow X. The flow Y2 results from the encoding of the flow X by a first recursive convolutive encoding. The flow Y3 results from the encoding of a permutation, the term "interleaving" being a misnomer, of the bits of the flow X by a second

recursive convolutive encoder. A turbo encoder thus uses at least two convolutive encoders, which are preferably systematic recursive encoders, the second one being preceded by a temporal interleaver working on blocks of a fixed size.

An interleaver/permutator is an essential component of turbo codes. A conceptual interpretation of the mode of operation is given in an article by G. Battail "A Conceptual Framework for Understanding Turbo Codes", IEEE Journal on Selected Areas in Communications, Vol. 16, No. 2, February 1998. Very briefly, it may be recalled that an interleaving, if it is properly done, enables the imitation of a random encoding. It must also be recalled that the role of a random encoding is central in the demonstration of C. Shannon's theorem of capacity. It is generally agreed that there are two very important factors for the designing of an interleaver of this kind. The first factor is the depth of this interleaver. The depth is the size of the interleaver, namely the number n of bits that it is capable of permutating. The greater the depth, the better it is, i.e. the more effective the random character will be. The second factor is the degree of randomness that can be introduced by the interleaver into a given block. An ideal interleaver is therefore a purely random interleaver but this does not exist in practice.

Indeed, the purpose of an interleaver is to break the least significant code words which are the most numerous to be transmitted. It is furthermore possible to design non-random interleavers that effectively deal with the least significant code words. However, these interleavers unfortunately tend to amplify the effects of the most significant code

words, and this is not desirable either. The criterion that enables the choosing of an optimum interleaver must consider the codes of all significance values simultaneously, and must obtain a general optimum. The determining of this criterion is an as yet unresolved problem.

The interleaving techniques used in the real systems of the state of the art use matrices. These matrices are implemented with hardware circuits. In such hardware circuits, the data elements or bits of a block are entered in lines, matrix line after matrix line. They are then read in columns. Simulations show however that the performance characteristics obtained with such matrix interleavers are lower than those obtained with interleavers produced by computer programs that imitate randomness.

Furthermore, third-generation cellular radiomobile communications, especially in the context of the IMT 2000 recommendation, require the use of a wide variety of services associated with temporal bit rates and constraints that are different from one another. Given the performance characteristics of the turbo codes, there is a likelihood of using them for services that require high protection against errors but accept a certain delay (that of the interleaver). The problem not resolved by matrix systems is then the permanently fixed character of the dimension of the data blocks liable to be processed. These permanently fixed dimensions result from the size of the matrices chosen and their write-read system.

Thus, if it is assumed that there are k different services, each bearing temporal delays of r1, r2, ..., rk bits, the aim, for each service, is to seek to make an interleaver of maximum depth, it being known that the interleaving performance characteristics rely on the size of the interleaver.

One difficulty of the matrix implementation that is conventionally proposed is that it is necessary to rigidly specify the different interleavers for the different sizes of blocks.

It is an object of the present invention to overcome these problems. It proposes the designing of an interleaver made in a software manner, that furthermore requires only very few parameters in memory. In the invention, for a block of n bits to be interleaved, with k ranks numbered 1 to n in the string of bits to be transmitted, another block of n bits of an interleaved string is created by permutation. The ranks of the bits in the interleaved chain are then h ranks, such that $h = f(k)$. The function f must be a permutation of $\{1, ..., n\}$ namely, a bijective application of $\{1, ..., n\}$ in itself. In the invention, to obtain the function f, a linear congruency equation is applied. It can be shown then that the choice of such an approach has the effect of doing away with the need for specific circuits and of furthermore requiring only small resources in software. The random character is thus not theoretically perfect but its approximation by a simple congruency algorithm is quite efficient with respect to the problem of improving the performance characteristics of the encoding of the channel sought.

An object of the invention therefore is a method of transmission with channel encoding, between a transmitter and a receiver, wherein:

- a binary string of n bits to be transmitted is encoded with a first encoder to obtain a first encoded string,

- bits of the binary string to be transmitted are permutated to obtain another binary string known as an interleaved string,

- the interleaved string is encoded with a second encoder to obtain a second encoded string,

- the binary chain to be transmitted and/or the first and/or the second encoded strings is/are transmitted from the transmitter to the receiver,

- and the transmitted strings are received and decoded correspondingly on the receiver side to reconstitute the binary string to be transmitted,

characterised in that

- to permutate the bits of the binary string of n bits to be transmitted, a k rank bit of the binary string to be transmitted is assigned a rank $h_k$ in the interleaved string which depends on a rank $h_{k-1}$ assigned to a k-1 rank bit of the binary string to be transmitted, so that the rank $h_k$ assigned is of the type:

$h_k = a.h_{k-1} + b$ modulo m, a, b and m being integers

The invention will be understood more clearly from the following description and the examination of the appended figures. These figures are given by way of an indication and in no way restrict the scope of the invention. Of these figures:

- Figure 1 is a functional representation of an encoding device that can be used to implement the method of the invention;

- Figure 2 is a flow chart of steps of the interleaving method of the invention;

- Table 1 which is an explicit part of the invention comprises preferred values of parameters under preferred variants of implementation of the algorithm of the invention.

Figure 1 shows a functional view of means of implementing a method of transmission according to the invention. This method is designed to be implemented between a transmitter 1 and a receiver 2. The transmitter 1 and the receiver 2 are shown symbolically and are connected to each other by a channel 3. The method of transmission with channel encoding of the invention is of the type that converts a flow of data elements X produced by the transmitter 1 into several flows of data elements Y1, Y2, Y3, Yi transmitted by the channel 3. The channel 3 will mostly be a radioelectric channel, with an encoding circuit 4 implementing the method of the invention, interposed between the transmitter 1 and the receiver 2, furthermore comprising an associated radioelectric transmission circuit that is not shown. In reception, circuits are adapted to the decoding and receiving, in correspondence, of the strings Y1, Y2, Y3, Yi and to the rebuilding of the transmitted string X.

The channel encoding circuit 4 comprises a first convolutive encoder 5 that produces a string of bits Y2 from a string to be encoded X. In one example, this convolutive encoder is a recursive convolutive encoder. In its principle, it comprises a certain number of delay circuits 6 to 9, cascade-connected with one another, the outputs of which are connected to adders or more generally to operators 10 to 13. The purpose of the operators 10 to 13 is to combine together bits of the string X available at a given date with bits of this same string, or of a conversion

of this string, available at a subsequent date. The convolutive encoder 5 shown is said to be recursive because the convolution products, especially those coming from the operator 12, are combined at the input of the system in an operator 13 with as yet unprocessed bits of the string X of the bits to be encoded. As indicated here above, the making of a recursive convolutive encoder is preferable because, for equal encoding complexity (and equal protection efficiency), a recursive encoder of this kind requires fewer operators and delay circuits than a non-recursive encoder that carries out a same conversion. This being the case, in the invention there is therefore no need in principle for the encoder 5 to be a recursive convolutive encoder. It could be a simple convolutive encoder or even another system of encoding of the BCH or Reed-Solomon or other type, but the performance characteristics will be different.

In addition to being transmitted as such in the string Y1 or in a convoluted form in the string Y2, in the invention the string of bits to be processed X is transmitted in the form of a third string Y3 encoded by another encoder 14 that also receives the string X of bits to be encoded. The particular feature of the string Y3 is that it is produced from a permutation of the string X of bits to be encoded. This permutation is obtained by a permutation circuit also called an interleaver circuit 15, interposed between the input of the encoder 14 and the input of the encoding circuit 4.

The left-hand side of Figure 1, gives a view in one example, in a 12-bit string X, of the processing operation performed bit by bit by the interleaver 15, to convert the chain X into a permutated string X'. The

interleaver 15 is preferably a software interleaver and its conversion algorithm is shown in Figure 2. In accordance with what has been referred to here above, to permutate the bits of the n-bit binary string to be transmitted, in this case twelve bits in one example, a k rank bit of the binary string X to be transmitted is assigned a rank $h_k$ in the interleaved string X'. The particular feature of the invention is that the rank $h_k$ in this string X' depends on the rank $h_{k-1}$ assigned to a bit with the rank k-1 of the binary string X of the bits to be transmitted. The dependency is such that:

$$h_k = a.h_{k-1} + b \text{ modulo } m$$

In this formula a, b and m are integers, parameters of the conversion. To be complete, a complementary parameter, which is essential to the invention, is the number n of the bits of the string X to be encoded. Indeed, as indicated in the introduction, the invention enables the adapting of the encoding to the length of the words to be transmitted. For example, in the context of the GSM system, it is known that, on a useful window of 156 bits, only 142 bits have informational significance. Among these 142 bits, three groupings are formed. A first grouping and third grouping represent information elements to be transmitted. A second intermediate grouping, which is intermediate between the other two groupings, comprises consistency information enabling a channel decoding circuit, in reception, to retrieve the two groupings of bits expected, and improve the transmission performance characteristics of the channel. Other standards can be envisaged. Even in GSM, it is possible to adapt high bit transmission protocols. In this case, the key

lengths of the words to be transmitted is no longer 142 bits but may be greater. For example, it may be 1024 bits or more.

Thus, during a step 16, in the program implemented by the interleaver 15, the values of the parameters n, a, b and m are defined. Hereinafter we shall see the constraints that weigh on judicious choices of these parameters, where non-compliance with these constraints leads to the deteriorated functioning, even if it may be acceptable, of the encoding algorithm of the invention. After the step 16, during a step 17, the string X of bits to be transmitted begins to get scrutinised. This is done in the form of two instructions 18 and 19, respectively an instruction 18 k=1 and $h_k$ = 1 followed by an instruction 19 k = k + 1. The instruction 18 actually means that the rank 1 bit in the string X to be transmitted will be assigned a rank $h_k$=1 in the string X', before it is encoded by the encoder 14. This is not an obligation. In particular, it can be envisaged for k = 1 to choose an initial value of $h_k$ that is different from 1. It is quite simply enough that $h_k$ should be smaller than n. The fact of choosing $h_k$ as being different from 1 may lead, as referred to here above, neither to excessively penalising nor to giving excessive advantage to the least significant or most significant bits. If need be, it may be planned that $h_k$ will change its value for each new string X undergoing a permutation. The step 17 is followed by a test 20 during which it will be ascertained that the rank k bit to be processed truly belongs to the string X of n bits or that it belongs to another string, consecutive to the string X, that also is an n bit string. If this is not the case, and at the beginning it is not the case, then it is

possible to find the rank $h_k$ by applying the instruction 21 knowing that a, b and m are known.

If they are produced in this way, the values $h_k$ are not necessarily distributed randomly throughout the string X of bits. Furthermore, it is even possible in certain cases that the conversion 21 is not a permutation of {1, 2, ..., n}. In order that these criteria might be obtained, it is necessary to impose certain constraints on the parameters a, b and m. Indeed, the sequence (infinite) defined by the linear congruency of the step 21 has a period m if, and only if, b and m are prime numbers in relation to each other; if, for any prime number p dividing m, a - 1 is a multiple of p; and if a - 1 is a multiple of 4 when m is a multiple of 4. A justification of these constraints can be found in the article by Hull and Dobell, SIAM Review, 4 (1962), pages 230-254. In practice, it is enough to take m = n +1 to produce a permutation.

In the example shown in Figure 1, it is sought to permutate twelve bits. We can then take m = 13. It is indeed important that m should be greater than n. Hereinafter we shall see how m can be taken to be greater than n to resolve certain difficulties of the algorithm. a and b remain to be chosen. The choice of b as being different from zero amounts to choosing $h_k$ as being different from 1 for k = 1. Most of the time, b = 0 will be chosen. However, to go from one permutation to another, with only one algorithm implemented according to the step 21, it is enough to add b (modulo m) to the rank of each bit produced by the interleaver 15 in which b will have the value zero. Thus, in Figure 1, the encoding circuit 4 may comprise other encoders to produce other strings

Yi of encoded bits. Rather than starting each time from the string X and providing for another complex interleaver 15, it may be more useful in this case to start from the string X', change the value of b and thus constitute an additional interleaver at lower cost by an addition of b modulo m, to feed another encoder.

Hence, a remains to be chosen. In one example, it is possible to arbitrarily choose a so that it is about half of n or half of n - 1. For example here, we choose a = 6. The implementation of the step 21, with a = 6 and b = 0 for m = 13, then gives the following results, the first line giving the rank k of the bits of the string X, the second line giving the assigned ranks $h_k$ in the string X:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 6 | 10 | 8 | 9 | 2 | 12 | 7 | 3 | 5 | 4 | 11 |

This example is furthermore shown in the left-hand margin of Figure 1. The first line shows the ranks k of the bits of the string X of the bits to be processed, the second string shows the ranks $h_k$ that have been assigned in application of the step 21 to these bits with a rank k of the string X. As shown in the step 18, the bit with the rank k = 1 is arranged and stored in the rank $h_k$=1 in the string X' of encoding bits. For the bit with the rank k = 2, the formula 21 is applied. This gives a rank $h_2$ = 6 x 1 + 0 modulo 13 in taking b = 0. The operation 6 x 1 + 0 gives 6, with modulo 13 not changing the result. This leads to assigning the k =2 ranking bit a rank $h_k$ = 6 in the string X'. For the bit with the rank k = 3,

the application of the formula gives $h_3$=6x6+0 modulo 13. This gives 36 modulo 13 or 10. And so on and so forth all the ranks $h_k$ are assigned. It being known that the bits of the string X may be produced by the generator 1 progressively, the interleaver 15 then comprises a register 22 wherein, in a step 23, the generator 1 is made to arrange and store the bits of the string X'n as and when they are produced, as a function of the place assigned to them by the step 21. The arrows shown in the register 22 pertain to this arranging and storage process 23.

If it is sought to permutate a fixed number n of bits and if m = n + 1 cannot verify the constraints (which is rarely the case), it is possible to find an m' greater than m, obtain the permutation by means of a linear congruency in m' and then strike out the number greater than m. For example, if it is sought to permutate ten bits, it is possible to take as here above, m = 13, a = 6, b = 0 and $h_1$ = 0. We then obtain

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 6 | 10 | 8 | 9 | 2 | ~~12~~ | 7 | 3 | 5 | 4 | ~~11~~ |

We then eliminate the values 12 and 11 and obtain a randomly organised sequence:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 6 | 10 | 8 | 9 | 2 | 7 | 3 | 5 | 4 |

By acting in this way, for m strictly greater than n + 1, a rank $h_{k+1}$ is properly assigned in the interleaved string to a rank k bit of the binary string to be transmitted, when the rank $h_k$ normally assignable in the

interleaved string is greater than n, for all the bits with a rank greater than k of the binary string to be transmitted. Indeed, a rank 7 has been assigned in the interleaved string to the rank 7 bit in the binary string to be transmitted whereas the rank 12 normally assignable in the interleaved string is greater than 10. A shift of this kind is made for all the bits with a rank greater than 7, namely the bits with the rank 8, 9 and 10 of the binary string to be transmitted. In the example shown, naturally the elimination of the rank 11 has no influence since this rank is the last one assigned. Nevertheless, the principle of shift thus evoked has been applied several times.

The step 23 is followed by an iteration by branching between the instructions 18 and 19. When, at the test 20, the rank of the bit produced by the generator 1 becomes greater than k, then the word contained in the register 22 is read in a step 24, and the encoder 14 is made to encode it. The string Y3 of the bits processed is then transmitted in the step 25 by a transmission circuit and sent in the channel 3. To make the processing by the encoder 14 more fluid, it is possible to provide for a second register 26. The second register 26 thus belongs to the interleaver 15. In this case, during the reading of the chain X' and the encoding and transmission of the bits contained in the register 22, the interleaver 15 sets up another string X' of permutated bits. In this case, simultaneously with the step 24, the algorithm of Figure 2 comprises a branching 27 at a following n bit word, to a following chain X to be processed.

Hereinafter in Table 1 here below, examples are given of values of parameters a, b and m.

**Table 1**

| a | b | m |
|---|---|---|
| 6 | 0 | 13 |
| 5 | 0 | 17 |
| 7 | 0 | 257 |
| 206 | 7 | 1025 |

In practice, the choice of the parameters a, b and m is made through a pragmatic approach, by comparing the overall performance of the encoding with different permutations. It will be possible however to provide for an automatic algorithm that computes these parameters from a given number n.

In this computation, in a first step, m = n + 1 is chosen. Then, a is chosen to be about half of m or n. The condition of b and m as prime numbers with respect to each other is then naturally obtained by choosing b = 0. Then, a search is made for all the prime numbers p dividing m. And a search is made for a so that a - 1 is a multiple of p, whatever the value of p. For example, on a string X of n = 1024 bits, m = 1025, which is not a prime number, is tried. Then, m is reduced to a prime factor. It is thus possible to write 1025 = 5 x 5 x 41. This leads to a choice, for a, of the value 5 x 41 + 1. That is, a = 206. It is then ascertained that m - a is a multiple of 5 and 41. It is then possible to define b as a function of the rank of the interleaver 15 in the set of interleavers used in the encoding circuit 4. If there is only one, then b will be equal to 0. If there are two, then for the first, b will be equal to 0 and, for the second, b will have another value, for example a/2.

The implementation of the algorithm of the invention requires the multiplication of the ranks $h_{k-1}$ by a. This does not raise any difficulties in view of the speed of the operators presently available in the processing circuits. The addition of b is an operation that generally uses only one cycle period. The congruency, modulo m, may be obtained with a simple shift of the reading of the result produced by the adder which adds b or of the multiplier by a. The fact of choosing b = 0 naturally has the advantage of eliminating an operation, the shift being done in this case on the result of the multiplication.

The advantages of the approach of the invention as compared to the prior art are:

- very great simplicity in the making of the interleaver 15 (design, cost, etc.);

- better performance if specific bit rates and time constraints have to be complied with;

- a purely software management requiring very little memory, only that of the register 22 and very rarely over 10 Kbits;

- adaptability to the different services that exist during an initial implementation as well as adaptability to subsequent modifications if any. It is indeed enough to modify the program represented by Figure 2.

If the random character has to be modified as explained here above, it is possible to add b to the computed ranks $h_k$. As a variant, it is possible to perform an iteration of the method on the $h_k$ values found. In this iteration a, b and m may be the same or may be changed. Then new ranks $h_i$ are assigned to the preceding ranks $h_k$.

## CLAIMS

1. Method of transmission with channel encoding, between a transmitter and a receiver, wherein:

- a binary string of n bits to be transmitted is encoded with a first encoder to obtain a first encoded string,

- bits of the binary string to be transmitted are permutated to obtain another binary string known as an interleaved string,

- the interleaved string is encoded with a second encoder to obtain a second encoded string,

- the binary chain to be transmitted and/or the first and/or the second encoded strings is/are transmitted from the transmitter to the receiver,

- and the transmitted strings are received and decoded correspondingly on the receiver side to reconstitute the binary string to be transmitted,

characterised in that

- to permutate the bits of the binary string of n bits to be transmitted, a k rank bit of the binary string to be transmitted is assigned a rank $h_k$ in the interleaved string, which depends on a rank $h_{k-1}$ assigned to a k-1 rank bit of the binary string to be transmitted, so that the rank $h_k$ assigned is of the type:

$h_k = a.h_{k-1} + b$ modulo m, a, b and m being integers.

2. Method according to claim 1, characterised in that m = n + 1.

3. Method according to claim 1, modified in that m is greater than n + 1 and in that a rank $h_{k+1}$ is assigned in the interleaved string to a k rank bit of the binary string to be transmitted when the rank $h_k$ that can be normally assigned in the interleaved string is greater than n, for all the bits with a rank higher than k of the binary string to be transmitted.

4. Method according to any one of claims 1 to 3, characterised in that b and m are prime numbers in relation to each other, in that, for any prime number p that divides m, m – a is a multiple of p, and in that a – 1 is a multiple of 4 if m is a multiple of 4.

5. Method according to any one of claims 1 to 4, characterised in that b is equal to 0.

6. Method according to any one of claims 1 to 5, characterised in that the encoding is a recursive convolutive encoding.

7. Method according to any one of claims 1 to 5, characterised in that the parameters a, b and m are given values corresponding to one of the lines of the following table :

| a | b | m |
|---|---|---|
| 6 | 0 | 13 |
| 5 | 0 | 17 |
| 7 | 0 | 257 |
| 206 | 7 | 1025 |

8. Method according to any one of claims 1 to 7, characterised in that the assigning of the ranks is reiterated by assigning new ranks ($h_l$) to the ranks ($h_k$) already assigned.

9. Method of transmission with channel encoding, between a transmitter and a receiver, substantially as hereinbefore described with reference to the drawings.

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INVESTOR IN PEOPLE

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**Application No:** GB 9929541.2 **Examiner:** Gareth Griffiths
**Claims searched:** All **Date of search:** 9 June 2000

# Patents Act 1977
# Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H4P (PEL)

Int Cl (Ed.7): H03M 13/27, H04L 1/00

Other: Online Databases: WPI, EPODOC, JAPIO

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
|---|---|---|
| Y | WO98/48517 A1 (GENERAL ELECTRIC) fig.1 | 1, 6 at least |
| Y | WO97/05702 A1 (FRANCE TELECOM) p.11lines 23-27 | 1, 6 at least |

| | | | |
|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
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